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U. S. DEPARTMENT OF AGRICULTURE.

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IRRIGATION
OF SUGAR BEETS.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,

Washington, D. C., March 10, 1910.

SIR: I have the honor to transmit herewith a paper prepared under the supervision of Samuel Fortier, chief of irrigation investigations of this Office, by F. W. Roeding, irrigation manager in charge of the work of this Office in California, discussing in a practical way the irrigation of sugar beets. The success attained in the growing of sugar beets in Colorado, Utah, Idaho, and California, where the irrigation of beets is practiced, leads to the conclusion that large areas can be devoted to the culture of the sugar beet and that this industry will help greatly in the development of the immense tracts now being brought under irrigation. This development can be greatly promoted by the adoption of the best methods of applying water to the beet fields, and this bulletin is prepared for the purpose of supplying information as to these methods.

Mr. Roeding wishes to acknowledge assistance in collecting information on which this paper is based to the following agents of the irrigation investigations of this Office: A. P. Stover, in Oregon; John Krall, jr., in Idaho; O. W. Bryant and his assistants, in Colorado; Prof. W. W. McLaughlin and his assistants, in Utah; D. H. Bark, in Kansas; and H. I. Moore, in Montana, while the writer has covered his own field in California. The cooperation of the Great Western Sugar Company in the experiments conducted during the seasons of 1905 and 1906, and of the American Beet Sugar Company, covering the past four years, is also acknowledged, as well as the assistance and advice given by the officers of the various sugar companies throughout the territory covered.

It is recommended that this paper be printed as a Farmers' Bulletin.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.



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IRRIGATION OF SUGAR BEETS.

INTRODUCTION.

The discovery of a method of extracting sugar from the beet was made in 1747 by Professor Margraff, a member of the Academy of Science, Berlin, Germany, but no practical use was made of it until the beginning of the next century, when his pupil, Achard, started a factory in Silesia.^a This was followed by the rapid establishment of factories throughout Germany and France and marks the beginning of the extensive development of the industry in Europe. In 1907 Europe's total production of beet sugar amounted to 6,575,000 tons, or nearly one-half of the world's production of beet and cane sugar for that year—14,230,372 tons.^b

The introduction of the industry into the United States was very slow and was accompanied by many vicissitudes. Although attempts were made as early as 1830, it was not until 1879 that a successful factory was established at Alvarado, Cal., which commenced operations that year and has been in operation ever since. Although this factory and a few others established shortly afterwards were very successful and sugar manufacturing was encouraged by the payment of a bounty on all sugar manufactured in the United States from 1890 to 1894 and by a protective tariff at other times, it was not until the last few years of the past century that this important industry received the attention to which it was entitled. This was brought about largely by the discovery that sugar beets could be grown to great advantage throughout the West with the aid of irrigation.

During the year 1908 there were in operation in the United States 62 factories, with a daily capacity of nearly 50,000 tons of beets, requiring an area of about 365,000 acres and producing about 380,000

^a U. S. Dept. Agr., Bur. Chem. Bul. 27.

^b U. S. Dept. Agr., Yearbook 1907, p. 686.

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long tons of sugar. Factories were distributed among the various States as follows:

Number of factories and their capacities, by States, 1908.^a

State.	Number of factories.	Capacity per 24 hours.	State.	Number of factories.	Capacity per 24 hours.
California	8	9,100	Nebraska	1	350
Colorado	15	11,800	New York	1	600
Idaho	4	3,750	Ohio	1	400
Illinois	1	350	Oregon	1	400
Iowa	1	500	Utah	5	4,000
Kansas	1	1,200	Washington	1	500
Michigan	16	11,550	Wisconsin	4	2,300
Minnesota	1	600	Total	62	48,600
Montana	1	1,200			

^a U. S. Dept. Agr., Rpt. 90, pp. 51-53.

In segregating these various factories into irrigated and unirrigated sections, we have—

Number of factories and their capacities in irrigated and unirrigated sections.

	Number of factories.	Capacity per 24 hours.
Irrigated	36	31,950
Unirrigated	26	16,650
Total	62	48,600

It appears that approximately two-thirds of the beet sugar is produced in the irrigated sections of the West, and the industry's greatest development will probably be there. The need of the development of the sugar industry in the United States is shown by the following table:

Consumption of sugar in the United States, 1909.^a

	Tons (2,240 pounds).
Importation from Hawaii and Porto Rico	718,788
Importation from other sources	1,674,776
 Total	2,393,564
Domestic production, cane sugar	409,960
Domestic production, beet sugar	434,000
 Total production of the United States	843,960
 Total consumption of the United States	3,237,524

In other words, almost 75 per cent of the sugar consumed is imported.

^a Willett & Gray's Weekly Statistical Sugar Trade Journal, Jan. 6, 1910.

The area in which sugar cane can be grown in the United States is limited to a small portion of the country bordering on the Gulf of Mexico, and the industry is at present confined to Louisiana and Texas.

SCOPE AND PURPOSE OF THIS BULLETIN.

A practical manual, giving methods pursued throughout the irrigated beet-growing sections and thereby furnishing information to new settlers in irrigated districts, as well as suggestions to beet growers as to the practices in States other than their own, should be of value in introducing the growing of beets and improving the methods of handling this important crop. As the matter now stands, each community where this industry has found favor is proceeding along lines suggested by local conditions which are more or less peculiar, and this bulletin is designed to be a compilation of the practices throughout the West, to which are added the results of experiments conducted by this Office in irrigation of sugar beets during the past four years.

The information from which this bulletin is compiled was obtained by the various field men of this Office, by personal contact with the most successful growers in the irrigated beet-growing sections, and also with the officers of the various beet-sugar factories. The collection of these data extended through the crop season of the year 1908, while the experiments which were conducted at Rocky Ford and Loveland, Colo., date from and include 1905. The territory covered included the Pacific coast and the great interior valleys of California, the Grande Ronde Valley in Oregon, the Upper Snake, Payette, and Boise valleys, in Idaho, the South Platte and Arkansas valleys in Colorado, all the beet-growing sections of Utah, the Billings district in Montana, and the Garden City district in Kansas.

SOILS AND CLIMATE SUITED TO THE GROWING OF SUGAR BEETS.

Soils suitable for the culture of the sugar beet under irrigation comprise practically all classes, from the heavy black adobe and gumbo soils of California and Montana to the sandy loams and silts of river bottoms and mesas. The clay and clay-loam soils require much more work than lighter soils, and are more difficult to put into proper tilth. The forming of a crust after rains or after being irrigated is also a disadvantage. These soils, however, contain a much larger percentage of available plant food than the lighter soils, and under favorable conditions will produce heavier yields and are not so easily exhausted by continuous cropping. Intensive tillage, which is so important in the cultivation of this crop, has a marked tendency to render these heavy soils more friable, and it has been found that the yields in-

crease from year to year up to a certain point. In the Pajaro Valley of California, where beets have been grown since 1888, some of the black adobe soils gave the largest returns after ten years of continuous cropping without fertilization.

The depth of the soil is one of the prime considerations in the growing of sugar beets, as the beet is deep rooted. Therefore, lands with a hardpan formation within 18 inches of the surface should be avoided, not only on account of their interference with root growth, but because of their tendency to lose moisture. Low, wet lands should be avoided also, no matter of what character, as they are usually "cold" and prevent any rapid development of the crop in the early stages of plant life, while the later growth is kept beyond the time when the beets should mature, thus causing low sugar percentages.

Alkali is to be considered also, especially as most soils throughout the West contain alkali in greater or smaller quantities. Beets will withstand the effects of alkali to a greater degree than any other summer crop, but strongly impregnated soils retard the proper development of the plant as well as lower the purity of the juice, rendering it unfit for manufacture. The white alkali or sulphate salts are far less harmful than the black or carbonate salts, but lands which show a considerable white crust in the early spring are not suitable for beet culture, while black alkali or salt lands should never be used.

Taken altogether, the best soil for this crop is a clayey loam of good depth, which contains sufficient sand or silt to allow its being worked into a finely divided condition. The underlying soil stratum should be pervious to water but not so coarse as to allow of rapid percolation. Such soils are found in nearly all the present beet-growing districts and are usually the producers of large crops of beets of good sugar percentage and high purity. As provided for in the contract between the beet growers and the sugar manufacturers, the selection of land suitable for this crop is subject to the approval of the latter's field men or superintendents. As these men are usually experienced, their judgment should be relied upon largely.

Climate naturally has an important bearing on the desirability of a district for beet culture, and in a general way it may be stated that at least four or five months of growing weather are necessary to the successful production of beets. The Bureau of Chemistry of the United States Department of Agriculture has made an exhaustive study of the subject throughout a long period of years and has published a number of bulletins giving the results of its investigations. The success which has attended this industry throughout the arid and semiarid regions may be attributed largely to the distribution of the rainfall. The absence of rain at the time of harvest is an

important feature, as it permits the beets to mature. In the more humid sections of the East and Middle West rain may cause a renewal of growth after maturity, which results in a great reduction in the sugar content of the beet. The West, therefore, where moisture is applied artificially and can thus be regulated to cause maturity at a certain stage, is without doubt an ideal field for the successful fostering of this industry. From a study of the meteorological conditions of the older beet-growing sections it is found that the mean annual temperature ranges from 47° F. in Utah and Colorado to 63° F. in southern California, from an absolute maximum of 111° at Chino, Cal., to 100° in the more northern coast region, and from an absolute minimum of 28° on the southern California coast to -38° at Fort Collins, Colo.^a

Rainfall, although not so important in irrigated sections, shows from 20 to a little less than 8 inches as the mean of the various points. With the exception of California, the portion of this that falls during the summer months, from May to September, inclusive, is 25 to 70 per cent of the total annual precipitation. May, June, and July are usually the months of greatest precipitation, which, although it can not be relied upon on account of the local character of the storms, is of considerable help to irrigated fields. In California practically no rain falls from May 15 to October 1, but the mild winters permit of early planting and a growth during the rainy season. Frost and hailstorms, if not too severe or too early, injure this crop probably less than any other, and it is therefore reasonably safe in high elevations. The fields of Colorado and Utah are all between 4,000 and 5,000 feet elevation, while fairly good crops have been produced at an altitude of 6,000 feet. All things considered, however, 5,000 feet may be considered as the maximum elevation at which success can be attained.

PREPARATION OF LAND FOR IRRIGATION.

The proper leveling of land is fully as important with this as with any other crop, and upon this feature of the work the securing of the best yield will very largely depend. It usually entails a considerable expense, but pays for itself many fold, and it would be far better for the beginner, if funds are limited, to restrict his area to a small acreage and put it in proper shape than to endeavor to handle a large area of poorly prepared land and meet with partial failure. In the latter case he will not only encounter difficulty in distributing the irrigation water evenly, thereby causing endless labor and trouble, but with unevenness in the surface it will be impossible to prevent the drown-

^a Absolute maximum and minimum are the highest and lowest of which there are records.

ing out or scalding of his crop in the depressions. This fact can not be emphasized too strongly. In selecting the area to be devoted to this crop a fairly level field or one having a uniform slope is desirable. If the land surface is uneven and the preparation entails considerable cutting down of mounds and filling of hollows it will result in a spotted field, as all the top soil containing the organic matter will be moved off of the high places and this will expose raw soil, which will need heavy fertilizing to sustain plant growth. Furthermore, lands which have never been in cultivation should not be used for sugar beets.

METHODS OF IRRIGATING.

As already stated, environment and physical conditions have tended largely to determine methods of irrigation in various localities, but with the exception of California, and to some extent the Kansas and Idaho fields, the furrow method is adopted almost universally and the advantages of this method over others can not be doubted.

In California checking and bordering for sugar-beet irrigation are largely practiced and the furrow method is unknown. This may be ascribed to various causes, the principal one being that fields are largely winter irrigated; that is, water is applied before the crop is planted. The disposal of the waste waters from the factories, which were forbidden an outlet in any of the fresh-water streams of the State, due to their polluting influence, led to their use on lands near by. When the manufacturing season opened it was too late to apply this water to growing crops, so it was spread over fields which were vacant or had been harvested. In order to facilitate and cheapen the distribution of water which ran day and night the land was leveled and checked, and it was thus possible for one man to handle a large area. Large checks are avoided, the average size being from a fraction of an acre to $1\frac{1}{2}$ acres. The results from this practice proved so favorable that not only is the factory waste water thus used, but in some sections all the land devoted to beet culture is winter irrigated.

Winter irrigating is also practiced in the fields of Kansas, southeastern Colorado, and Idaho, where late water can be obtained in the ditches. The winters throughout this section are generally very dry, so that when spring approaches the soil contains so little moisture that it can not be worked until the heavy spring rains occur. Evaporation is small during the cold weather, and if water is applied in the late fall the land is in shape in early spring for preparation. The advantages of this practice are obvious, for if the spring is dry it is necessary to irrigate before preparing the land, and this always

presents the danger of rains following an irrigation and preventing the working of the soil until too late.

Where water is applied without previous preparation, as in southern California, slip-joint pipe is used. This pipe is usually made of light galvanized iron in lengths of 12 feet. It is moved about the field easily and does away with the evaporation or seepage loss common to earth ditches. When pipe is used, only a small area near the discharge point is covered by the aid of a shovel, then a section

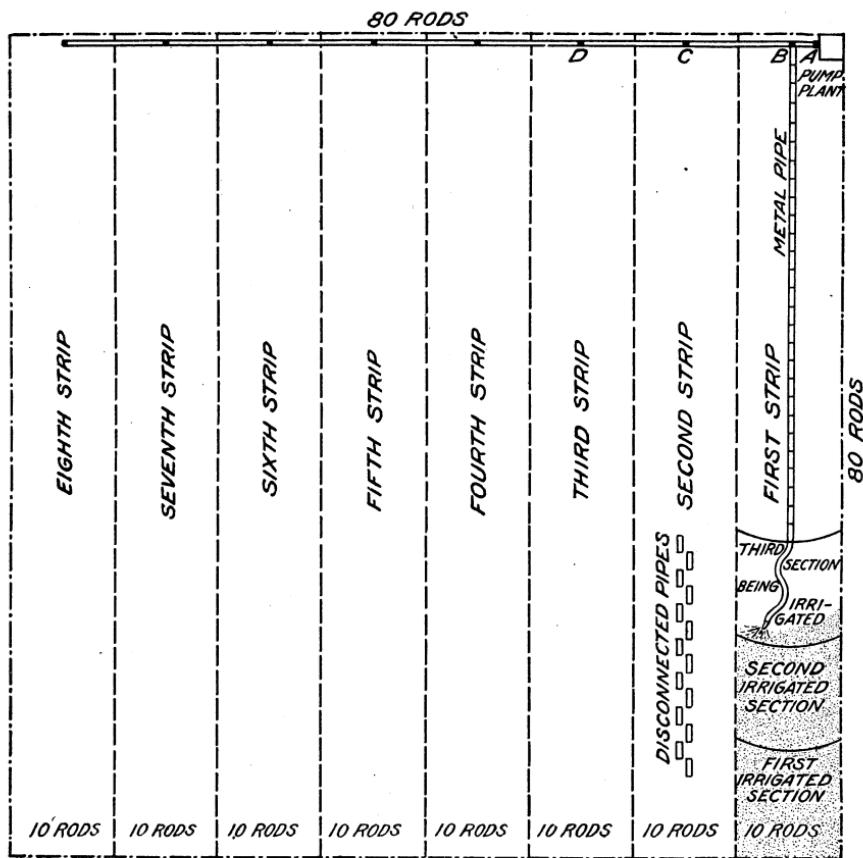


FIG. 1.—The use of slip-joint pipe in applying water to land.

of the pipe is taken off and another patch wetted, and so on across the field, the pipe being laid in any direction necessary, regardless of the rows (fig. 1).^a In this district water is scarce and its cost high, whether from pumping plants or gravity systems, so that it is necessary to exercise the greatest economy.

In the neighborhood of Lewiston, Utah, and in southeastern Idaho a method of subirrigation is practiced, due to the peculiar soil con-

^a U. S. Dept. Agr., Farmers' Bul. 263.

ditions. Seepage ditches are plowed out to a depth of 1 foot or so and placed across the field at intervals of 100 to 150 feet. At the time of irrigating they are run full of water, which moves laterally from them through the soil on account of the almost impervious clay subsoil. This method is similar to the one employed in alfalfa fields in the Gallatin Valley of Montana, but its use is not to be recommended, as it tends to raise the water table and causes alkali to accumulate on the surface.

ADAPTING METHODS TO LOCAL CONDITIONS.

The furrow method of irrigation has given without doubt the most satisfactory results, and it is possible to apply this system to fields having any configuration of surface from an almost perfect level to steep slopes, the quantity of water applied to each furrow and its depth and length being arranged accordingly. Flooding in checks or in borders, without previous leveling, as practiced in California on account of local conditions, has answered its purpose, but where irrigation is an absolute necessity during the growing period the furrow method will be found to meet the requirements far better than any other. Its first advantage is in the cost of preparing the fields and the ease with which they can be kept in condition; second, the ease with which the water applied can be kept from touching the plants and thus forming a crust of earth around them. This is acknowledged by all experts on this subject to be a decided advantage. The ideal condition is brought about by the maintenance of a continuous good mulch close to the beet itself so as to prevent evaporation from the soil surface, and by cultivation after irrigation to break up the wetted area in the furrow into a finely divided condition. Furthermore, the furrow system leaves the surface in shape for any other crop which may be used in rotation.

Checks and borders in the field interfere more or less with the planting, working, and harvesting of the beets, prevent the danger of drowning out beets by careless application of water, and make considerable waste ground in the field. Levees are seeded like the rest of the field, but, being above the surface of the checks, they do not receive much moisture and usually the beets are small.

FURROW IRRIGATION.

Preparation for irrigation in furrows entails giving the surface a uniform slope throughout, so that water may run through the furrows without interruption. On lands which are fairly level a leveler or float is the commonest implement used. This is generally homemade and is fully described in a previous bulletin of this series.^a

^a U. S. Dept. Agr., Farmers' Bul. 263.

The land should first be plowed in lands to a depth of 8 or 10 inches; plowing around a field should always be avoided, and all dead furrows should be eliminated as far as possible by back furrowing into them several times. The lands should therefore be of con-

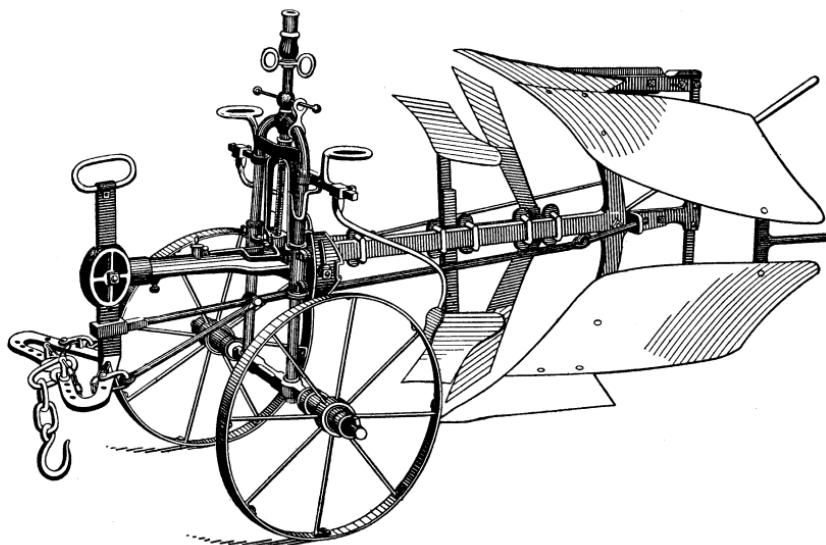


FIG. 2.—Reversible plow.

siderable width, even if time is lost at the turns. In this connection it may be well to speak of a type of plow which is coming largely into favor in many of the beet-growing sections and which does away entirely with both back and dead furrows, since all furrows are

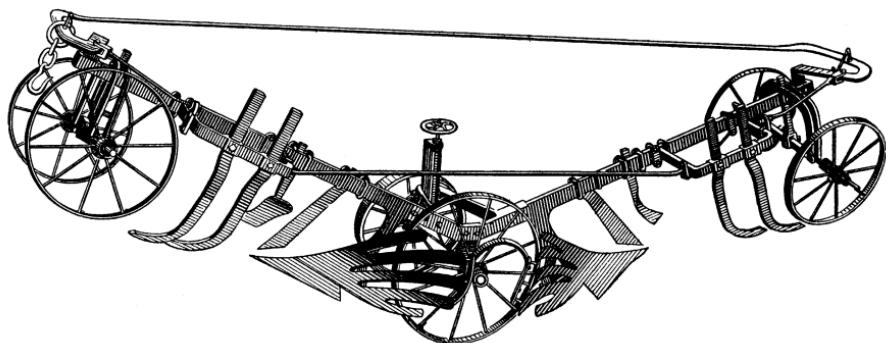


FIG. 3.—Balance plow.

thrown in the same direction. This plow is a sulky and is made in two types, called "reversible" (fig. 2) and "balance" (fig. 3). The reversible consists of right-hand and left-hand plows set opposite each other on a beam. When the end of the field is reached the

plow is thrown out of the ground and reversed by means of handles at the back, and when the implement is turned around the other plow throws the furrows in the same direction as the previous furrow. Another type, accomplishing the same purpose, consists of a sulky frame carrying right and left plows, with levers for raising and lowering the plows so that either one can be held out of the ground while the other is in use. The balance plow consists of one or several plows in gangs, fastened to two frames, which are set at an angle of 135 degrees to one another, the axle and wheels being at the angle (fig. 3). One frame contains right-hand and the other left-hand plows. The drawbars at the ends are joined by means of a heavy round steel rod (fig. 3), and a loose ring connects the team to the drawbar, so that when the end of the field is reached the team is swung around on the unplowed ground and the ring travels from one drawbar to the other by way of the rod, and as the plow starts up it pulls one plow out and the other into the ground, thus obviating the necessity of throwing the plow out as in the reversible. On larger areas engines are used. These have become quite popular also with sugar companies farming their own lands. The outfit consists of two traction engines and the balance type of plow. The engines are fitted with drums by which the steel cables attached to the plow are pulled backward and forward between them. This method permits of very deep plowing, up to 24 inches, as no energy is wasted in traction and the entire power is exerted on the plow. As soon as one engine has drawn the plow to its side of the field it moves up to a point opposite the new furrow which the plow will make when pulled back. The advantage of this type of plow, not only in preparing land for irrigation but in keeping the surface in a uniform condition after preparation, can not be overestimated.

A disk harrow should follow the plow as soon as the plowed soil has dried sufficiently to pulverize without clogging the spaces between the disks. The harrow should lap half its width on the previously disked ground, thus going over the field twice at one time and filling the furrow left between the two disk sections. Harrowing across the disking will place the surface in a fairly well-pulverized condition. After the prepared ground has laid several days, to permit settling and drying, it is ready for the leveler (fig. 4). This should run first across the harrowing, then with it, and finally diagonally across both ways. In running across the field so often the operator will be able to detect unevenness and to use the cutting blades with considerable skill and can then decide whether it is necessary to go over the field again. He should, however, always keep in mind the advantages of well-leveled ground and spend rather too much time in its preparation than too little. With a float (fig. 5), which is not provided with a cutting blade, the fills or cuts are made by the driver shifting the

weight of his body along its length. The only advantages in a float are that it requires the services of the driver only and its construction is cheaper, while two men are required to run the leveler. Otherwise the operation of the leveler is more satisfactory. The main ad-

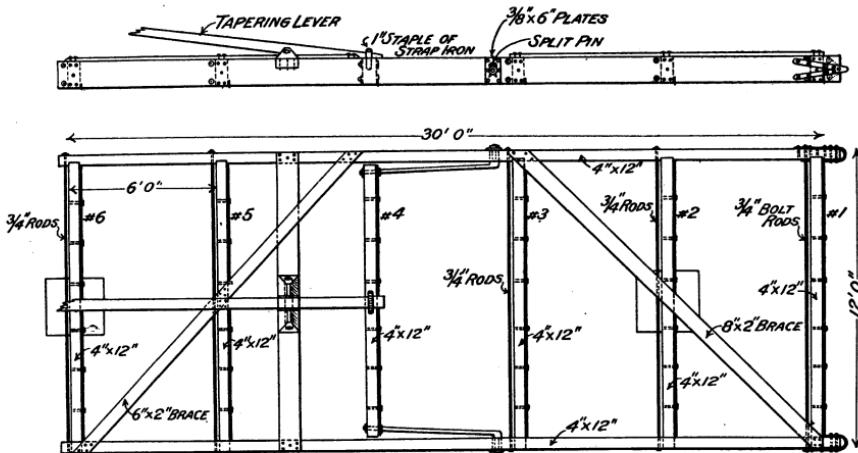


FIG. 4.—Rectangular leveler.

vantage in either implement is in its length, and this should be not less than 18 feet.

Where land is more uneven the use of the buck or dump scraper is required to cut off high ground and fill up the low places. This

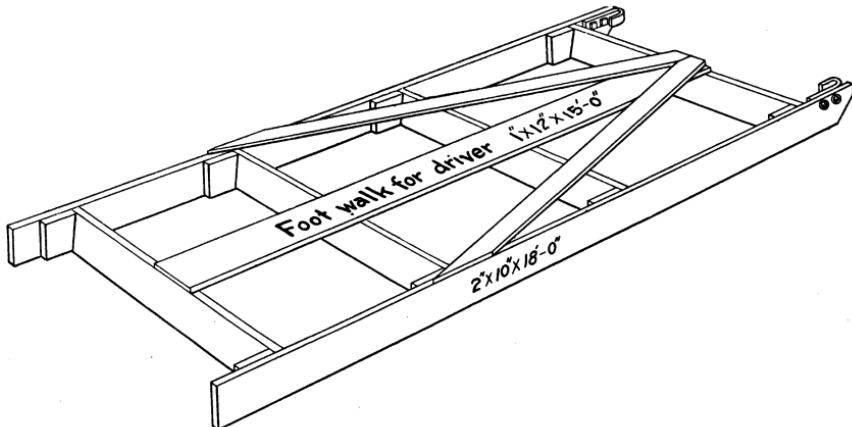


FIG. 5.—Float for leveling land.

should be followed by the leveler or float after plowing and harrowing as described above. If after the scraper work is completed there are not sufficient rains to settle the soil which has been dumped in the depressions, it is well to irrigate the land in order to settle it thoroughly. If this is not done it will be found that the fills will

settle later below grade and cause an uneven field even though the land appears level on completion of the work.

Taking for granted that a drill with furrowing attachment has been used in seeding, thus marking the rows, the first step is to furrow out either with furrowing shovels attached to a cultivator, using the shield on either side to prevent the furrowed earth from being thrown above the seed, or with the furrowing sled, so much used in the Arkansas Valley.

The furrowing sled.—This sled is constructed in various ways, but figure 6 shows one which gives the best results. It is made of 6 by 6 inch timbers 42 inches long as runners, and spaced wide enough to straddle two rows. These timbers are set to run on edge and are sharpened at the forward point and armed with old furrowing shovels, which about fit them. The runners are securely spiked together at the back end with 2-inch boards upon which the driver rides, and are connected in front by a 4 by 4 inch timber, to which the draft is attached. Either one or two horses are used, two being

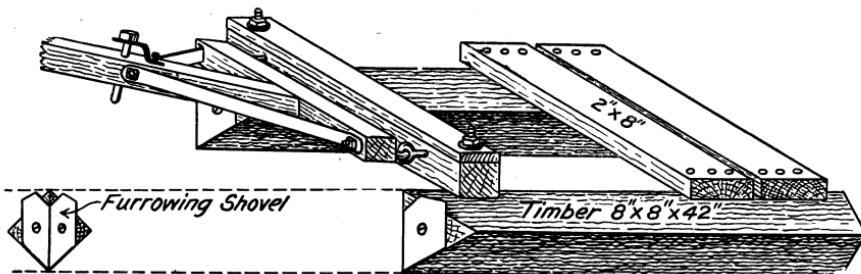


FIG. 6.—Furrowing sled.

preferable, as there is not so much danger of the sled shifting from its line. This implement makes a smooth, even furrow, without clods to interrupt the flow. With it furrows can be placed in alternate rows or every row, as desired. In the latter case a furrowed row would be straddled. More runners could be placed on the sled to furrow out more than two rows at a time, except that slight unevennesses in the surface will prevent the making of as good furrows. Smooth furrows, especially for irrigating up the seed, are most essential and no other tool can be secured to give as good results as this homemade device. More crude forms are made of two straight limbs of cottonwood, 5 or 6 inches in diameter, for runners.

The two-row or four-row beet cultivator with long-winged furrowing shovels attached is probably more largely used in making furrows than any other implement. Ten acres per day can be covered with the four-row cultivator, and 5 acres with the two-row implement with one or two horses and one man, while preparing the field with the furrowing sled after cultivation requires about two or three times as

much work. The advantage of the sled is in the lesser cost of the implement, which would be a decided advantage on small fields and the better work in making furrows and distributing water.

If at the time of irrigation the soil under the mulch has become dry and hard, a cultivation with deer or bull tongues in the center between rows to loosen the packed soil will be found helpful, as it permits the making of good, deep furrows, and overcomes the resistance which a dry, packed soil has to water. When furrowed out with the sled, as described already, a deep, smooth runway for the water is obtained. When the furrows are made with the furrowing shovel a deer tongue or soil-loosening tool can be placed in front of the furrowing shovels and the whole operation completed at once. After the rows have been furrowed out, as described, it is necessary to prepare head ditches from which water can be turned into the furrows. This is accomplished by plowing out a ditch parallel to the field lateral which serves the area. The head ditch is then cut into sections with earth dams, each section serving a certain number of rows, according to the grade of the ditch, and connected by a gate to the lateral ditch. The bank next to the furrows is cut for either one or two furrows and the water turned on. By having head ditches the water can be well distributed and several sections can be running at the same time if there is sufficient water. The amount allotted to each furrow should be small, so that it will run slowly and secure a good saturation, as well as prevent wetting the soil over the seed. At intervals of 300 to 500 feet there should be cross ditches which will intercept waste water from the rows above them and also supply water to the lengths of rows below. It is a grave mistake to attempt to run water the entire length of a field if this is more than 500 feet, as the upper end will become too wet before the water reaches the lower end. The slope naturally determines the distance between cross ditches, and where this is considerable they can be spaced at greater intervals, but on flatter areas 300 feet or even less will be found sufficient. Cross ditches are made by simply plowing out dead furrows with a good-sized plow, either single or double moldboard. If parallel head ditches are placed along each cross ditch it will result in the destruction of too many beets, so that here the water is run to the lowest point on the cross ditch and turned into a section of rows. When these are irrigated a dam is thrown in and the water diverted to the next section. By having a waste ditch around the lower end of the field the water can be regulated to the required quantity.

Lath boxes or tubes in ditch banks.—The amount of water distributed to the furrows can be controlled better by the use of small lath boxes or sections of tin or iron pipe placed in the lower banks of the ditches. The former have been in use at Rocky Ford, Colo.,

and in southwestern Idaho for some time, but their use has been very limited, due to the extra labor entailed in placing and removing them, but the saving in labor due to the better regulation of the water applied to each furrow does not seem to have been considered. When made of lath, as shown in figure 7, they leave an opening about 1 inch square. Their length should be at least 2 feet, while 30 inches is better, so that they will protrude a little each side of the bank. If well placed they will give a very uniform flow into the furrows, but if one runs more than another the simple device of partially closing the opening with a few blades of grass will give the desired results. The boxes are also made so that two opposite sides project beyond the others a couple of inches, as illustrated. The advantage in this is that the opening can not be entirely closed by the lodgment of floating material against it, and also, when desired, the flow can be stopped better by wedging material between the projecting sides.

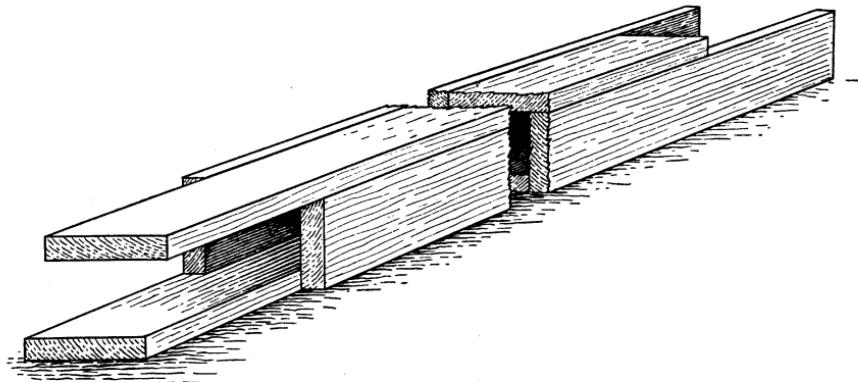


FIG. 7.—Lath box for distributing water to furrows from head ditch.

Old water pipe of 1 to $1\frac{1}{2}$ inches in diameter, cut in lengths of 2.5 feet, or, better still, round, well-soldered tin tubes of the same length and diameter, will be found cheap and efficient. Figure 8 shows the arrangement of the field just described.

The method of irrigation practiced in Payette and Boise valleys, in Idaho, is worthy of particular mention. Lath boxes for either one or two furrows are placed in the banks of the field laterals. The banks are constructed higher than would be absolutely necessary and the boxes placed somewhat higher than the level of the land. Check gates are placed in the ditch at intervals, so that the water may be held at a uniform height above the boxes, giving an equal head over all boxes and producing a uniform flow. The flashboards in the gates are lower than the crest of the banks, so that should a larger stream than is necessary for one section of the ditch be turned down it will waste over the top of the gate into the next section of the

ditch. In this way a good many furrows can be receiving water at the same time, and one irrigator is sufficient to watch them. Where night irrigation is practiced the ease of distributing the water after it is once regulated, and therefore the small amount of labor entailed, is a decided advantage. When the furrows from one section of the ditch are all sufficiently wet the removal of the flashboard lowers the water so that no more will run through the boxes in that section. The only criticism which can be made of this system is the danger of the lath boxes washing out. Where either iron or tin

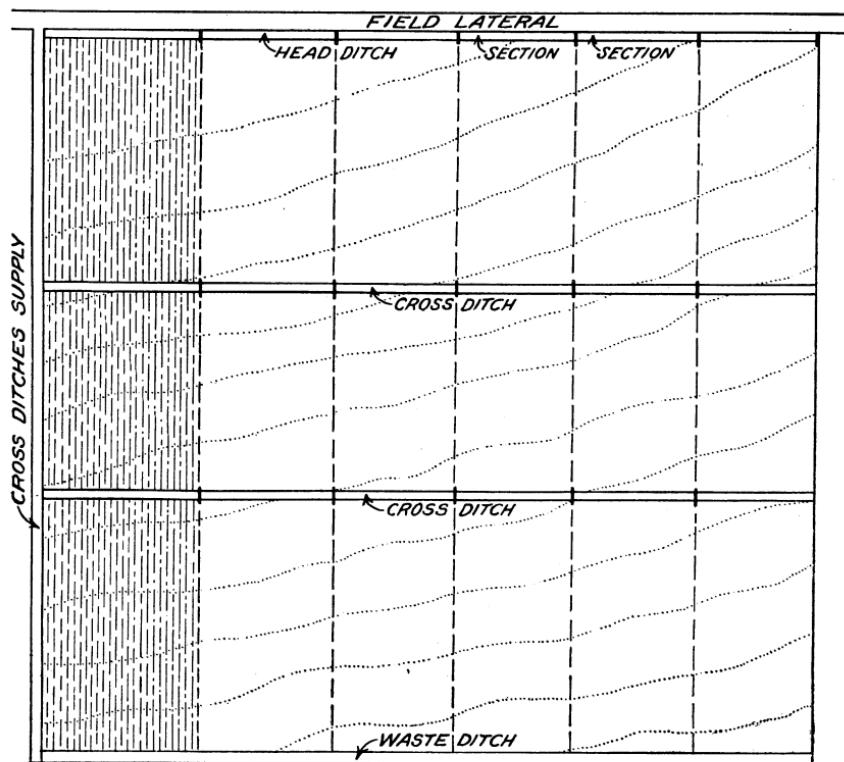


FIG. 8.—Plan of field-furrow irrigation.

pipes are used this danger is obviated very largely, as there are no joints from which leaks can occur to cause a break. Furthermore, by having a tin flange 6 or 8 inches square soldered on at the middle point of the tin pipe, which would prevent water running along the outside, breaks could be done away with entirely. The expense in arranging such a system is considerable, but this is fully repaid in the saving of labor and water and in the uniformity of the irrigation.

Where furrow irrigation is practiced without boxes, head ditches are placed along field laterals of considerable size and the cut-outs are made in their banks for one to four rows each. Wooden gates

are placed in the lateral ditches to hold up and divide the stream, and outlet boxes connect the head ditches to the laterals. This is the best practice, as it permits of regulation without continual watching. If a lateral is small, the cuts are made in its bank. Where the soil is heavy there will be little or no wash, but in lighter soils the cuts will have to be watched closely or the entire bank may be washed away. The use of this method permits of the handling of large quantities of water and rushing it over the field quickly, but it is little better than a flooding, as it is next to impossible to distribute the water to a large enough number of furrows and keep it divided evenly so that it will not run over onto the beets. Where the fall in the ditch prevents an even distribution of the water to the various cut-outs, the simple device of placing a few sticks in the bottom and throwing in some weeds on the upstream side will check the flow and cause a slight rise above the obstruction.

THE CHECK METHOD.

The check methods followed in California for preparing beet fields are the same as those employed so largely in preparing land for alfalfa,^a except that in some sections, like the Santa Maria Valley, the border checks are temporary, being leveled down when the land is prepared for planting. Gates for the checks or borders are also avoided, as they would interfere materially in the planting and harvesting of the fields.

In the check system a field is divided into rectangular basins or checks by levees, and lateral ditches are run between the lines of checks so that water can be distributed to both sides of a ditch. The checks nearest the head of the ditch are filled first by throwing a temporary earth dam or a canvas dam across the stream and cutting the banks. Each set of checks is filled in turn until the lowest is reached. In this way, should breaks occur, the water will cover the lower lands without waste, and finally, when all checks on that lateral are filled, there are no cross dams to be removed. The same process is employed with both temporary and permanent borders.

THE BORDER METHOD.

Even when the land is irrigated in border checks, furrows can be placed and better results obtained than if the water is flooded over the land without runways, but beets which are planted on the crests of the levees will not develop like those within the checks, and the tonnage per acre will be smaller.

In the Garden City, Kans., district, the border method is practiced, both with and without furrows. The borders are temporary

^a U. S. Dept. Agr., Farmers' Bul. 373.

and are 50 to 80 feet apart, the length varying from 300 to 1,000 feet, according to the slope and character of the soil. The rectangular or contour checks must be flooded, but where the soil is heavy and the downward movement slow some provision should be made to remove the excess water so that it will not stand for any length of time. This is done usually by cutting through a levee and drawing it off into a lower check. The practice followed sometimes in alfalfa fields of running water from one check to the others below without feed ditches would result disastrously if applied to this crop, as it would mean that the higher checks would be continually under water until the lowest is covered, and thus would a great part of the crop be drowned out or scalded.

The temporary borders are used only before planting, and consist of levees extending parallel to the slope of the land at intervals of about 10 feet. These checks are thrown up usually by back furrowing with a 14-inch or 16-inch plow. In irrigating the water is distributed evenly by the use of shovels, and as this work is done on the unplanted ground it is not necessary to have the land carefully leveled.

In other sections of the California and Kansas fields practically no leveling is done, the water being simply flooded over the land, between temporary borders running down the slope. A more detailed description will be found above. The cost of the various methods of preparation depends largely on the unevenness of the surface, but in general it may be stated as follows:

Cost of preparing land for irrigation.

	Per acre.
Furrow irrigation	\$5-\$15
Rectangular or contour checks	15- 35
Border checks	12- 25
Temporary borders	1- 4

Permanent field laterals are placed on the highest ground and arranged to give the most economical service. If it is possible to do so they should be placed along the borders or so distributed over the field that they will not interfere with the working of the land in large bodies. Their size is dependent upon the area to be covered, but care should be taken to have the bottom as near the level of adjacent land as possible, so that there will not be any large quantity of slack water in the ditches. This can be done best by throwing dirt from adjacent land onto the line of the ditch by means of a scraper, and then plowing out the center of this ridge and finishing with a "V" or "A." A slope of 0.05 to 0.02 foot in 100 feet is sufficient for laterals, but if necessary greater grades may be given, depending upon the size and location of the ditches and the character

of the soil. In the lighter soils the velocity of the water should not exceed 0.5 to 1 foot per second, otherwise there will be erosion and a consequent deepening of the ditches, so that the water can not be taken out at points desired, but in heavy soils greater grades may be given if necessary, as the danger of washing is less. The spirit level mounted on a tripod, or various other cheap contrivances, can be used for locating, and this is far safer than simply running by eye.

Where ditches are small and construction inexpensive, many farmers prefer to plow them out each year, as it does away with weeds along their banks. The cost of keeping a ditch clean will not be much less than that of making a new ditch, and if ditches are destroyed the plowing of a field as a whole can be done without interference.

SUBIRRIGATION.

In southeastern Idaho and northern Utah, where the seepage ditches are used, wells of riveted galvanized casing or wooden boxing are sunk to a depth of 5 to 10 feet so that the height of the water table may be observed. As stated before, this method can be employed only where the subsoil is sufficiently impervious to permit of a strong lateral movement. A warning not to attempt to make use of this system where alkali is present is extended, as it will bring the salts to the surface and render the land useless. This method requires very little attention, as the ditches are filled and regulated so as to hold the water at a certain height until the water table has risen to the desired height, where it is maintained throughout the growing season by regulating the supply in the ditches. This means a considerable loss through evaporation and is not as economical as surface irrigation, but it is practiced with good results in the districts mentioned.

Where no permanent structures are installed in the ditches to check the water the canvas dam is generally used (fig. 9). This dam is cheap, effective, and easily moved from place to place. The width and length should be sufficient to give plenty of bearing surface on the sides and bottom of the ditch. A little soil shoveled along its edge where the water covers it will make it practically water-tight. The best method of making these dams is to sew one edge over to form an opening for either a 2 by 4 inch or a 4 by 4 inch stick, as may be desired, according to the width of the ditch. If for a 2 by 4, 8 inches of one side would lap over and be sewed throughout its length, thus permitting the stick to be thrust through without trouble. When its use is no longer desired the stick can be withdrawn and the canvas folded up and put away for future use. This arrangement will preserve the cloth and also give a stronger hold than if tacked to the stick.

Tappoons made of sheet steel in various ways are used to some extent, but these are not as satisfactory as the canvas dam, particularly in a dense soil, as it is difficult to force them into the bottom or sides of a ditch to prevent the water from cutting under or around them. If earth dams are used the soil should be taken from the ditches below the dam, so that when it is cut the earth will be washed back and fill up the hole.

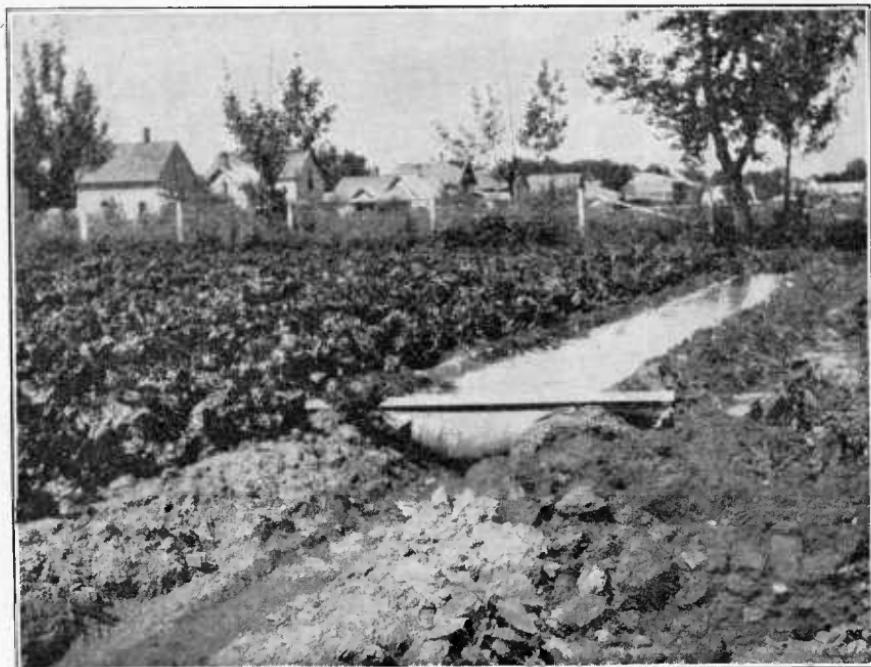


FIG. 9.—Canvas dam in lateral.

TIME OF IRRIGATING.

As already stated, it is essential that there be sufficient moisture in the soil at the time of seeding to bring the plants up, and it is better to irrigate before rather than after seeding. The next irrigation, or the first in case it is not necessary to irrigate to bring the beets up, should be delayed as long as there is sufficient moisture in the soil to keep up a steady growth. Too early irrigation tends to make a turnip-shaped beet and produces an unusually heavy growth of leaves without a corresponding development of the root. Figure 10 shows four beets from the experiment grounds at Loveland, Colo., which fully illustrate the advantages of holding off the water and forcing the plant to seek it with its taproot. The experimental field from which these plants were taken at harvest time was planted on

April 8, 1905. Plant No. 1 did not receive irrigation water until August 9; plant No. 2, on July 26; plants Nos. 3 and 4, on July 17. The number of irrigations during the season corresponds to the numbers shown on the photograph, that is, No. 1 was irrigated once, No. 2, twice, and so on. The year was an unusually favorable one, as rains were bountiful and well distributed, so that little irrigation was necessary. The soil was kept in a thorough state of tillage

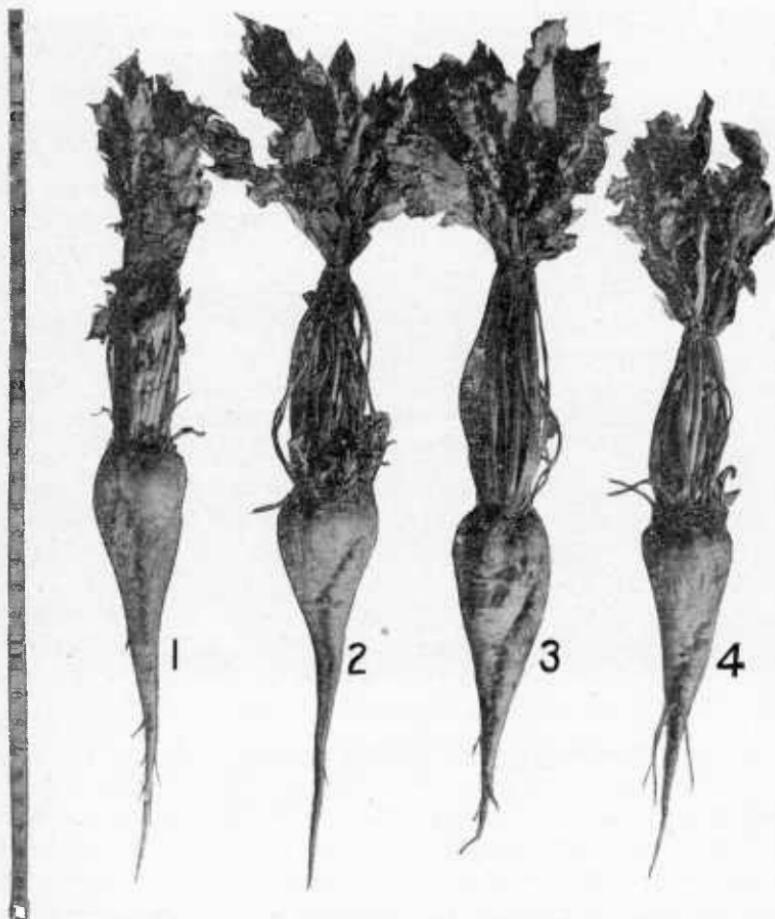


FIG. 10.—Beets, showing effects of early and late irrigation: No. 1, irrigated August 9; No. 2, irrigated July 26; Nos. 3 and 4, irrigated July 17.

by frequent cultivations, and the loss of moisture by direct evaporation was slight. There is a middle course as to the time of this application of water to the crop, for if held off too long the beet will begin to mature and so prevent its proper development later. Experience alone will decide the best practice, but in a general way it is no advantage to this crop to irrigate it when there is sufficient moisture in the soil to keep up a vigorous growth.

After irrigation and as soon as the soil has dried out sufficiently, a cultivation 3 or 4 inches deep should follow. The narrow cultivator shovel, bull, calf, or deer tongues should be used in order to pulverize the soil as much as possible. If the beets have become so large that the leaves would be injured, the use of these implements would injure rather than benefit the crop and should be avoided. The furrows will then remain as they are in furrow irrigation and serve for subsequent irrigations. If plants are not too large, the furrowing for following irrigations should not be put off too long after the cultivation, as there would be danger of injuring the leaves.

The time for subsequent irrigation will depend largely upon the weather. The beet leaves being of considerable size and the weather warm the evaporation from their surface is great and on hot days they will wilt, but this is no sign that another irrigation is required, for on examination it will be found usually that the soil contains considerable moisture, the beets wilting because the root is not able to supply moisture to the leaves fast enough to make up for the evaporation from their surfaces. As soon as night falls and evaporation is greatly curtailed the leaves will assume their normal condition. As long as the leaves look fresh and healthy in the early morning it is unnecessary to give them water, but should they show signs of wilt at that time another irrigation is necessary.

Two to four applications of water should be sufficient, except on very porous soil, where the moisture quickly drops below the point where the roots can reach it. Under such conditions more frequent irrigations are necessary.

In many of the irrigated districts there is a question as to the relative advantages of irrigating in the daytime or at night. In some sections where the supply is limited it is necessary to use water for the entire period in which it can be obtained, so that day and night irrigation is practiced. Again, many growers object to night work, as it deprives them of sleep and it is more difficult to control the water properly. Those who advocate night irrigation, however, have found that they obtain better results, especially where the temperature of the water is low. Their contentions are that the water will go farther, due to less evaporation; that the water is warmer at that time, on account of its exposure to the sun during the day; and finally, that there is far less danger of scalding or drowning out than during the hot period of the day. All of these contentions are well borne out by the facts. It may be stated also that the proper leveling of the field and the use of boxes or tubes for distributing the water to the furrows, as practiced in the Payette and Boise valleys of Idaho, would render night irrigation no more difficult than day irrigation, while results would be generally better.

The final watering, as a rule, should be four to six weeks before harvest, so that there will be ample time for the plant to mature and store its sugar. In this connection it may be well to call attention to the fact that if the beets mature during the warm weather, some time before they are harvested, the percentage of sugar will decrease gradually. Experience alone will decide the best practice to have the crop ready for the factory when it is at the proper stage of ripeness. The decision as to this latter question is entirely with the field men employed by the factory. At this stage they may visit the various fields in their districts and select beets, usually 5 or 6, at various points in the field. These are turned over to the factory chemist for analysis, and if the sugar percentage and purity are sufficiently high orders are issued to harvest the crop.

BEET CULTURE UNDER IRRIGATION.

PLOWING.

All sections are agreed upon the necessity of deep fall plowing. A depth of 8 to 10 inches should be the minimum and subsoiling from 4 to 6 inches below that will be found advantageous. Here, also, plowing around the field should be avoided. Where land is arranged for the furrow method of irrigation and the ordinary plow used, the direction should be only with the slope; plowing at right angles to the slope will leave the dead and back furrows in the field in such a position that even if smoothed over by cultivation they will prevent a uniform flow of water through the furrows. This plowing should be left without cultivation so that the soil may be well aerated and be able to catch and retain snow or rain without drifting or run-off. On land which is checked the direction of the plowing is not essential except as it affects permanent ditches, but either dead or back furrows would interfere with the even surface of the basins, and the former would cause cuts in the levees. Where fields have been winter irrigated in California they must be thoroughly cultivated after watering, so as to retain the moisture applied. Disking and harrowing the soil, as described for the leveling process, will be found to be the best means in most fields.

Excluding California, the plowed fields remain generally in their rough condition until spring, except as frost and moisture smooth them somewhat. In early spring a double disk, allowing the disk harrow to lap one-half on each round, would smooth up the surface. If the winter has been very dry and there is not sufficient moisture to sprout the seed, the land should be irrigated after disking. It is wise to do this as early as possible, for if delayed too long rains might closely follow the irrigation, making the soil so soggy that it would be impossible to work it until too late for planting. This

irrigation (furrow method) would consist of running furrows with either the two-row or four-row cultivator, with furrowing shovels attached, set 18 or 20 inches apart, as would be necessary for the beet crop, but larger quantities of water could be used and cross ditches would be needed only at intervals of 600 or 800 feet.

Whether the land is irrigated or not it should be plowed again in the spring, but not deeper than 4 to 6 inches, and then so prepared that the top soil will be well pulverized to a depth of 2 to 3 inches with a firm, moist bed below. It is well to remember that the beet is a very tender plant in the first stage of its growth and the slightest obstruction before appearing above ground will interfere and retard it; therefore the surface soil should be worked into as fine a mulch as possible.

When the field has been worked into as perfect a seed bed as possible it is ready for seeding. Many implements are used for pulverizing, depending upon the character of the soil—round, cutaway, and spading disk harrows, rollers of various types, spring-tooth and other harrows, cultivators, and clod mashers being among the most common types. The lighter soils are not difficult to prepare, and the more common farm tools can be used; but the heavier soils, which must be worked at a certain stage of dryness in order to prevent their becoming cloddy, are very often a problem to their owners. Should clods form, due to the inability of the farmer to work all his land at the proper stage, clod crushers or various types of rollers are necessary, but where rollers are used they should be followed by a harrow in order to loosen the surface soil. Ring or corrugated rollers will be found most efficient where hard clods are to be dealt with. Being heavy, their work is far more effective with uneven sets of disks or surfaces than that of rollers of the same weight having a smooth surface.

SEEDING.

The ordinary four-row force-feed beet drills made by various manufacturers are used for seeding. These drills are all of the shoe type, as a disk is not necessary where the soil is properly prepared. The seed is planted to a depth of 1 to 2 inches, depending upon the character and dryness of the soil. In the heavier soils, unless dry, shallow planting is necessary, so that the beet may appear above the ground as soon as possible before a rain crusts the surface. But in sandy soils, where there is no danger of baking, deeper planting is practiced. Press wheels follow behind the shoes, arranged so that the soil is firmed either side of the seed, but left loose directly over it. In many districts furrowing shovels are attached, which make small furrows between the rows. This is a decided advantage, and the practice should be universal throughout irrigated districts, as it shows

just where the rows are in case it should be necessary to irrigate or to break the crust formed by a rain before the beets have sprouted. Where the fields are of considerable area the sowing should not be continuous, as it will mean the employment of a large number of thinners to get the beets properly spaced before they become too large. A drill should sow 10 acres a day, and it is best to allow several days to elapse between sowings, so that the beets may be thinned at the proper stage of growth. When this is done it is well to harrow just ahead of the seeding each time, the harrow running at right angles to the rows. The distance between the rows varies considerably in different localities. In California plantings are made as narrow as 14 inches, while where summer irrigation is a necessity 18 and 20 inches is the rule. The greater width permits working the beets with horse implements without much danger of trampling the plants, and is therefore best. In some sections of northern Colorado it is common to alternate 16-inch and 24-inch rows, or 18-inch and 22-inch rows, the wider ones being used as paths for horse implements or for furrows in irrigating. The best spacing of rows is such as will permit the continuous cultivation of the beet, which is so essential to success, and also the furrowing of each row for irrigation. Rows should be run with the greatest slope of the field, except of course in the check system, where this would not apply and the rows are placed so that the drill has to make the least number of turns. The straightness of the row is also a consideration on irrigated areas and the factories very often drill in the seed for growers, providing the drill, man, and team at so much per acre. The teamster is usually a man of experience with a good, steady team, so that fields seeded in this manner show almost perfect alignment in the rows.

The quantity of seed sown varies with the locality, and runs from 8 to 25 pounds per acre. Light seeding is practiced in sandy soils along the California coast, where there is little danger of a crust or insect pests injuring the young plants, but in the clayey soils the use of 15 to 25 pounds is recommended, so as to be assured of a good stand. If it were possible to so distribute seed in the rows that the plants would come up properly spaced, considerably less than 1 pound per acre would be required. Although numerous drills which are claimed to do away to a large extent with the cost of thinning and excess seed have been tried, none of them has been successful, and the heavy sowing to secure a large number of plants evenly distributed throughout the row is found most satisfactory.

The time of seeding is important and naturally varies with the locality, particularly in California, where it extends from the end of October to May. In Oregon seed may be planted as early as the beginning of March, while in the colder climates the latter part of April to early May is the best time. As early seeding as the condi-

tions permit is always recommended, as this gives the beets a chance to develop considerably before the hot weather comes on and to mature before it becomes too cold. Should the young plants be damaged or partially destroyed for any reason, there is also the opportunity of reseeding and still obtaining a good stand before the season is too far advanced. Therefore, outside of California, the rule is to get the seed in the ground as soon as spring has fairly opened, while in the latter State plantings are so distributed that the crop may be ripening during the entire period of the factory run.

It is essential that there be sufficient moisture in the soil to sprout the seed. If there is not, it is far better to irrigate before planting, as already described, if not too late, than after seeding. Should unusual climatic conditions so dry out the soil after planting that the seed is not sprouting uniformly, and there is little prospect of rain, it becomes necessary to apply water artificially. This is one of the most critical conditions which the beet grower has to face, and good results are the exception rather than the rule. In such a contingency the proper leveling of the ground will show its marked advantage, as under these conditions, more than at any other time during the growing of this crop, it is necessary to confine the water to the furrows and prevent it from covering the soil over the seed. If this can be done, a good stand is assured. If the soil over the rows has been wet and a crust has formed after a rain or irrigation before the beets have sprouted sufficiently, it is very important that it be broken, as the plant at this stage is so slender and weak that the slightest obstruction will stop its growth. Various methods for breaking such crusts are practiced. The most common is to use the peg-tooth section harrow with the teeth set well back, at an angle of about 60° from the perpendicular, and harrow the field crosswise of the rows. This destroys some of the beets, especially where the plants are caked in the crust, but if sufficient seed has been planted there may be a good stand left. A roller, either corrugated or plain, is run crosswise of the rows to break a crust, but it has the effect of packing the soil. Seemingly, the best method is the use of "spiders" (fig. 11) on a beet cultivator, though this method occupies more time. Two spiders are attached for each row and run on either side. The sharp points of the implement, if not run too deeply, prick into and break up the crust without otherwise disturbing the top soil, and their use should be more general.

BLOCKING AND THINNING.

When the beet has four leaves it is ready for blocking and thinning. The packing of earth around the beet after thinning is desirable, as it is weakened by the removal of its neighboring plants, and this practice is strongly recommended by sugar companies.

The blocking consists in chopping out plants with a hoe, leaving them 1 foot to 8 inches apart. This was done with one stroke, and the remaining bunched plants are then thinned down to one by removing all the others by hand. The strongest plant should always be selected, but this is a difficult matter to regulate where the work is done by contract. Thinning to 8 or 10 inches should be sufficient,

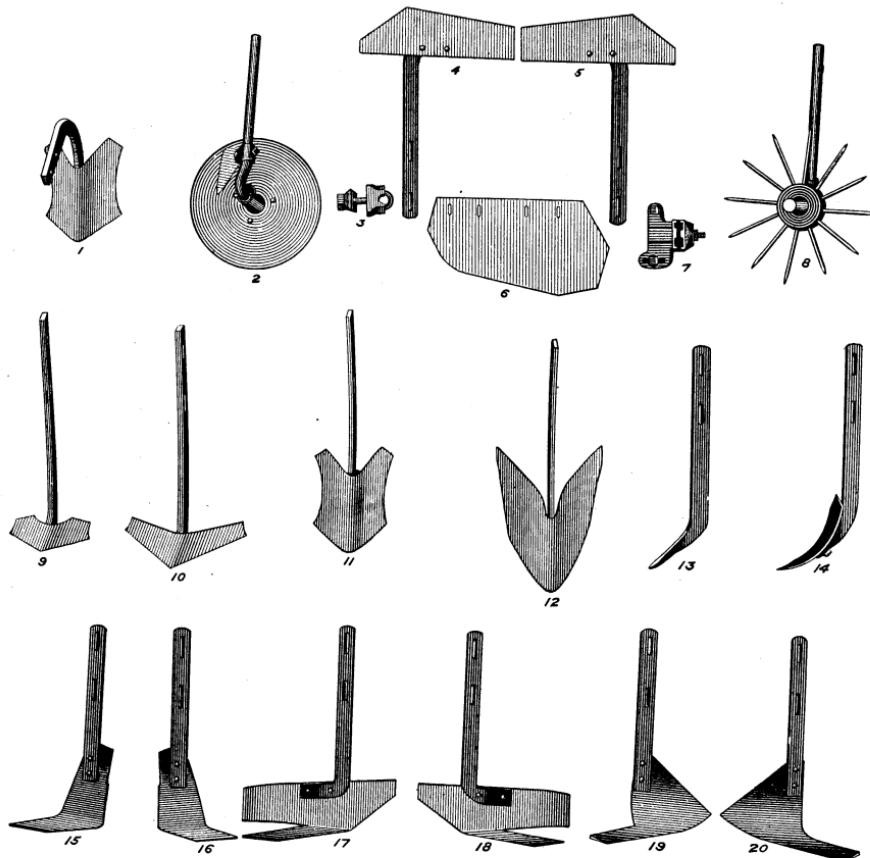


FIG. 11.—Weeding, cultivating, and furrowing attachments for beet cultivator: 1.—Seeder irrigating shovel. 2.—Disk weeder. 3.—Spider and disk clamp. 4 and 5.—Cultivator shields. 6.—Seeder shield. 7.—Reversible clamp. 8.—Spider. 9.—Duck foot No. 1. 10.—Duck foot No. 3. 11.—Irrigating shovel No. 1. 12.—Irrigating shovel No. 2. 13.—Deer tongue. 14.—Diamond point shovel No. 2. 15 and 16.—Weeding knife No. 1. 17 and 18.—Weeding knife No. 3. 19 and 20.—Weeding knife No. 5.

as this controls the size of the beet to a considerable extent. Beets weighing from 1 to 3 pounds are most desirable, as they contain higher sugar percentages and purity than larger beets, which accounts for the condition imposed in most contracts that beets weighing over 5 pounds each will not be received at the factory. As the beets come up thickly there is danger in thinning them of leaving two

plants very close together. As this work is done in a hurry some of the small plants are often overlooked, and it is usually stipulated in contracts for this work that one of the double plants shall be removed at the time of the second hoeing. By that time the beets have attained sufficient size to be noticed readily and the removal of the extra plant is important, for if two are left neither will become of any size. Thinning at the stage of growth specified makes considerable difference in the future development of the crop. If left until the growth is considerable the plants are weak and spindling, due to their crowded condition, and thinning at that stage sets them back.

After the beets are thinned the soil is packed by the feet of the thinners and a cultivation is necessary, but this should be shallow, as the beets have not rooted sufficiently deep to withstand any considerable disturbance of the soil. The implements most commonly used are shown in figure 11, and consist of the knives and duck foot which cover about 10 to 14 inches between the rows, leaving a space of 3 or 4 inches next to the rows so as to prevent clods being pushed onto the plants. This cultivation removes all weed growth, except a few inches on either side of the row, and loosens the top soil to a depth of an inch or two. Following this cultivation at the interval of a few days, a second hoeing should be given, which will consist in not only removing the weeds between the plants in the rows and spaces untouched by the cultivator, but in working the soil as close as possible to the beet. After the completion of the second hoeing a second cultivation should be given going to a greater depth than the first one, and in place of knives a narrow cultivator shovel, called a deer tongue or bull tongue, is most commonly employed. By this time the beets should be pretty well up and showing their first heavy leaves.

To conserve the moisture in the soil, frequent cultivations and one more hoeing are necessary. Continued cultivation at this stage of growth is of the utmost importance and pays for itself many times over in the increased yield. It removes the weeds which may still come up, thus preserving all the moisture in the soil for the beets, keeps the land warm, and prevents evaporation by destroying the capillarity. The fields should be cultivated every seven to ten days at this stage, or after each rain, the depth increasing as the plants grow larger.

HARVESTING.

It is often the case that at the time of harvest the soil in the beet fields has become hard and dry from the irrigations without subsequent cultivation and the absence of rain. The selection of the im-

plement to pull the beets depends largely on this condition. Figure 12 shows the ordinary beet puller, which is used where there is sufficient moisture in the soil or its nature is naturally loose, and it can

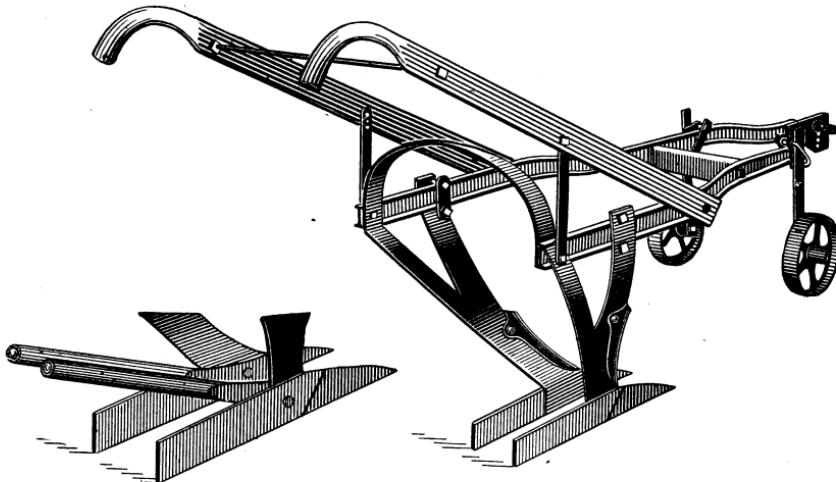


FIG. 12.—Beet puller.

be run to a depth sufficient to move the roots without breaking them near the surface and thus wasting a good portion of the crop. The prongs, as shown, run either side of the beet row and have a lifting effect which raises and loosens the beet. Two to four horses are

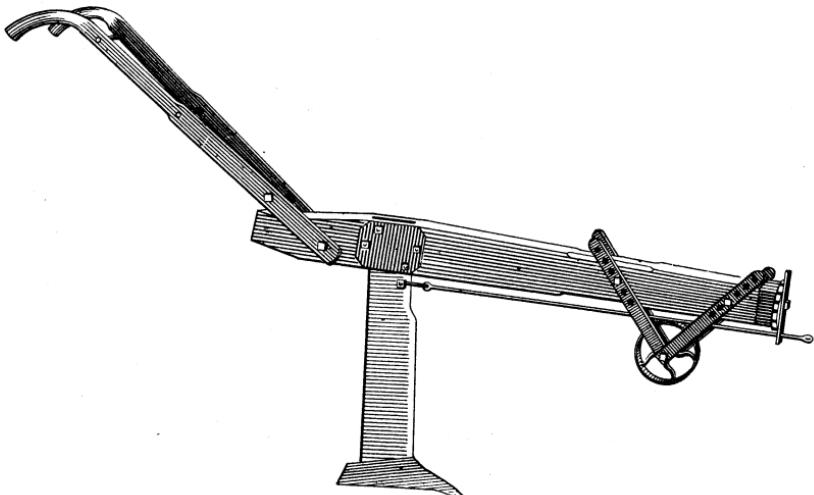


FIG. 13.—Beet plow.

required, depending upon the soil conditions and depths to which it is run. It is not sufficiently strong, however, aside from the damage it would do, to run in a hard, dry, clay soil. In such soils an implement similar to the one illustrated in figure 13, called a "beet plow,"

is used. This consists of a heavy steel standard somewhat similar to a subsoil plow, to which are attached, at the bottom, a plowshare and land side, the moldboard being absent. This plow is run as close to the row as possible, with the land side next to the row so as to prevent cutting the roots. Four horses are attached and it goes to a depth sufficient to loosen the soil so that the beets will come out as nearly whole as possible.

Another implement is adopted in large fields. It is very heavy and six rows are pulled at a time. It is used in connection with the double engine plowing outfit and is handled in the same way as the balance plow, described above (fig. 3, p. 15); that is, an engine is stationed at either end of the field and the puller is drawn back and forth between them. The lifting or cutting tool is on the order of a duck foot or sweep, with wide side wings made of heavy material. It is run to a depth of 18 to 24 inches and cuts the roots off at that depth, as the wings overlap and cover all the ground below between the outside extremities. As much as 30 acres per day can be pulled with this outfit, but its use is confined to large fields on account of the cost of operating.

After the pullers or plows come the topers with their long, heavy knives. Their first work is to throw the beets into piles, or windrows, after knocking them together to remove dirt. Six or eight rows, either side of the pile or windrow, are thrown together, and when the topers are up to the puller or plow they go back to top the piled beets. One man is given a rake or hoe with which he clears and smooths the ground between the windrows or piles, upon which the topped beets are to be thrown, so that in forking them into the wagon no foreign matter will be included. The topping consists of removing, with a blow of the knife, the crown of the beet at the point of the lowest leaf and throwing the topped beet on the cleared space.

Picking the beets up for topping by either slashing into them with the knife or having a sharp hook on the end of the knife for this purpose is forbidden by most factories, especially in the colder climates, as it has been found to cause rotting of the roots thus injured. If they are picked up in one hand and topped with the other the work is just as rapid, and where beets are siloed the loss will be little or nothing.

Where the pulled beets are thrown into piles a pile of topped beets is placed in the center of a square of four piles of untopped beets. If the pulled beets have been thrown into windrows the topped beets, from 20 to 25 feet in two windrows, are thrown together into a pile. The disadvantage of the windrows is that the topper has to keep moving to reach the beets, while when the beets are in piles they are close at hand and he may kneel at his work. Sometimes the beets are topped as they are pulled from the row and thrown either into a

wagon or into piles, but the method first described will be found to take little more time, if any, than the latter, while there is no comparison between the results. Care should be exercised that the pullers or plows do not get too far ahead of the topers, as it is desirable that the plowed-out beets be cleaned up each night.

In most of the present beet-raising districts the piling method is practiced. The harvesting is naturally cumbersome and expensive and inventors have been at work for a number of years trying to perfect a machine that will do away with the handwork, pull and top the beets, and load or pile them by means of elevators. A great many contrivances of this nature have been tried, but none has been found satisfactory. Where yields are good one man can top 6 to 10 tons a day. As the weather is usually cool at the time of harvest in the Rocky Mountain region, it is necessary to protect the piles of topped beets from frost, so at night those which are left in the field are covered with beet tops. This is a good practice and as a rule is demanded by the factory. It prevents not only damage from frost, but also drying out and consequent loss in weight if the beets are left in the field for several days.

In hauling a large, heavily-built rack with hinged side boards capable of bearing a load of 2 to 6 tons is used. Where the soil is too soft to bear the weight of the heavy beet wagons, sleds with boxes of various dimensions are used, the beets as they are topped being thrown into the boxes and when these are full they are hauled to the road and loaded into the wagons.

Beet forks made especially for this purpose have short handles and heavy tines with points protected so as not to stick into the beet. The wagons are arranged in various ways for dumping. Some have a heavy shaft extending lengthwise of the running gear, by means of which the entire rack can be dumped sidewise. Other racks break lengthwise in the center and the beets fall on either side of the wagon. Arrangements are also made at the dumps whereby one side of the rack is lifted against the chute by means of cables operated by machinery and thus relieved of its load. The use of nets made of light rope with a heavier rope around the edge is also popular. The net is spread over the rack before loading and is of sufficient size to lap over the side of the rack all around. In unloading one side of the net is attached to cables operated by machinery which pulls it out of the bed and throws the beets on to the dump, the other side being attached to the wagon sides. All these methods are to obviate the necessity of forking by hand, which is a hard, tedious process, and factories throughout the country have adopted these various methods of saving labor for their growers, as well as expediting deliveries. At the factories the loads are discharged into the bins constructed for

that purpose, but for shipping, elevated runways are provided close to the railroad track upon which the wagons are driven and the load dumped into flat cars. The most modern arrangement of railroad dump is a wooden platform at an elevation of about 15 to 20 feet, with runways at both ends, the grade of the runways being such that the heavily loaded wagons can be drawn to the platform without the aid of snatch teams. The chute which connects the platform to the car has a screen of heavy iron bars for a portion of its length, so spaced that sand, dirt, and trash can drop through, but no beets. The screen is provided with a hopper below, which conducts the foreign material in a load of beets to the wheelbarrow. A weighing station, presided over by a weighmaster from the factory, is provided at each dump close to one end of the runway. The load is weighed, driven up to the platform and dumped, and then driven back to the scales to ascertain the tare. To the tare is added the weight of the screenings from the chute. The wagons all bear the numbers given them by the factory field men and a record is made of the wagon number and its owner, so that it is unnecessary for weighmasters to inquire to whom beets belong. Platform scales are sometimes provided at each end of the runway, one for loaded and the other for the empty wagons, so as to prevent any delay in the weighing. From each load a sample of beets is taken in a bushel basket, the number of the load being marked thereon. These beets go to the factory where they are weighed, then cleaned with a brush, and green tops from improper topping removed, and weighed again. The difference is figured out in percentage, and a further deduction made from the load as determined by this method. This deduction ranges from 2 to 10 per cent or even more sometimes, according to the care in topping and the quantity of earth clinging to the beets. Where beets are paid for on a percentage basis these samples are further used to determine sugar content and purity. The process consists of slicing longitudinally a V-shaped piece to the heart of each beet in the sample, extracting the juice from these and making a determination with the polariscope. Weight tags are given to each grower for the loads delivered showing the net weight, less the screening, but the final tare, as determined in the factory, is usually ascertained later at the time of payment, unless beets are delivered direct to the factory, when the determination is made at once and shown on the tag.

A few of the less progressive factories do not provide weighing stations or elevated platforms at the shipping points, and each grower loads into his own car. This necessitates the use of a great many cars, delays in securing them at the proper time, and a general aggravation to the growers.

SILOING.

In the Rocky Mountain districts the harvesting of the crop usually takes place in October and November. The removal of the beets from the soil must be completed before the ground freezes and as the bins at the factories are not of sufficient size to store the entire crop, the piles of topped beets in the field are covered with earth to protect them, and this is called siloing. The process consists of making piles considerably larger and more carefully made than in topping for immediate delivery, each pile containing 1,000 to 2,000 pounds of beets. Earth is then shoveled over them to a depth of 5 or 6 inches, leaving a vent at the top, to prevent heating, on which a few beet tops are thrown. Should indications foretell exceedingly cold weather, more earth is piled so as to form a wall 10 or 12 inches thick.

If siloing is carefully done the beets will keep in good condition until orders for delivery are issued. As a rule, this is never later than January 31. If the soil cover is dry and the winter is without precipitation, some weight is lost in the siloed beets, but the extra amount paid by factories for such beets will, as a rule, fully compensate for the extra labor and loss. The smaller the silos the better the beets will keep, and piles of 1,000 to 1,200 pounds will be found preferable.

CROP ROTATION AND FERTILIZING.

The continued planting of any soil to the same crop will have the same effect on irrigated as on unirrigated land, the beet crop particularly being a heavy drain on soil fertility. Rotation, therefore, is an absolute necessity in maintaining the soil at its full productive capacity. This has been realized in all of the older beet-growing districts, and gradually a system is being evolved which will give satisfactory results. Alfalfa, the principal crop throughout the irrigated areas of the West, is the plant most used in rotation. It not only fertilizes the soil by its nitrogen-absorbing properties, but is deep-rooted and yields good returns. Methods of rotation as practiced in Idaho, Utah, and Colorado vary somewhat, but the best practice is very similar throughout and consists in the planting of beets for two or three years, depending on the fertility of the soil, followed by grain, which produces a heavy rank crop after beets, then alfalfa, or alfalfa with a nurse crop of oats. The planting of alfalfa with a grain nurse crop the first year after beets is not advocated, as the grain grows very rank and does not give the alfalfa much chance to develop, so the planting of alfalfa in the second year, with or without a nurse crop, is the best practice. The alfalfa is allowed to remain two to four years, three being the more general practice. It is then followed for one year by some cultivated crop, such as potatoes, melons, or corn, so that the weeds and alfalfa which remain may be

destroyed to a large extent, and then goes back to beets for two to three years. The method of plowing up alfalfa used in Idaho is strongly recommended. This consists of dragging or railing the alfalfa when the second crop has reached the blooming stage and plowing it to a depth of 3 or 4 inches, turning the sod completely. The plowshare should be kept sharp so that all the crowns may be cut at that depth, and a good disk coulter on the plow will be necessary to prevent clogging. By turning over the alfalfa at this time the plants will be more nearly killed out by exposure of the roots to the hot sun and the leaves and stems would have an opportunity to decompose and store humus in the soil. By following this with a deep plowing in the fall the land will be in good condition for the next season's crop. Disking and irrigating, if the land becomes dry, should precede the fall plowing. Clover and timothy are used also in rotation, and along the California coast beans are largely planted before beets, the latter crop being followed by grain.

Subsoiling below the plowing for the first crop of beets in connection with the above rotation should be practiced, as it will loosen the subsoil, which becomes hard and packed from the previous crop. This is not so necessary with the following crops of beets, as the puller or beet plow answers the same purpose.

The only fertilizer extensively used is manure and results from this have been excellent. The feeding of cattle and sheep with beet pulp, alfalfa, the waste molasses from the factories, and the beet tops in the field is common practice. Beet tops, however, would serve their purpose better, doubtless, if left on the ground and plowed under, and this condition is nearly always imposed upon the tenants who rent land from the sugar companies. In southern California the tops are raked and stacked and bring good prices, ranging from \$1 to \$3 per ton, as feed for cows. A number of companies deliver pulp to their growers without charge, the amount delivered to any grower not exceeding 20 per cent of the weight of beets delivered by him. This permits the grower to feed a number of sheep or cattle during the winter and produces fertilizer with which he can enrich his fields. From 7 to 20 tons per acre are used, spreading it during the winter and plowing it in with the opening of spring. Where continuous cropping is practiced this fertilization is very important, and as a proof of its value the field of the Great Western Beet Sugar Company may be mentioned. This field, containing about 100 acres, has been in beets ever since the factory at that point commenced operations in 1901. The crops averaged between 16 and 20 tons per acre each year and have shown no signs of decrease, due to the heavy application of manure each year. Rotation, however, is the cheapest and most normal scheme and shows the best results. Proper methods

in accordance with soil and climatic conditions must be studied and worked out gradually. The system described above has thus far proved successful in the regions mentioned, and it is therefore advocated as a basis in working out a better rotation.

CROP FAILURES UNDER IRRIGATION, AND REMEDIES.

Like all cultivated crops the beet has its insect enemies and diseases, but entire crop failures are unknown. A disease known as "blight," which seems to be peculiar to very dry years, is the most serious trouble with which the beet grower has to deal. All the older districts have suffered from it at one time or another. It shows its effect in the curling of the leaves and the discoloration of the sap and tissues of the root and usually attacks after thinning is completed. As it has occurred only at long intervals it need not be feared, except in periods of unusual climatic conditions. Another disease is a species of root rot which often attacks large, healthy beets and causes them to decay in a short time. This is somewhat similar to the die back in the cotton fields of the South and is never general throughout the field.

Insect enemies are numerous, but can be controlled by spraying, with the exception of those which attack the young plants at the time of sprouting. For these the only prevention is heavy seeding, so that a stand may be obtained even if many of the young plants are eaten. The Bureau of Entomology of this Department has published several bulletins on insect enemies of the beet and their control, which will be found of value in preserving this crop from insect depredations. Otherwise, crop failures are due entirely to insufficient work and attention on the part of the farmer and may be enumerated as follows: Poor leveling, poor plowing and preparation of the seed bed, thinning when beets are too large, lack of cultivation after thinning, permitting the fields to become weedy, and the improper application of water in irrigating, both as to the number of applications and the quantity of water used. In the latter case one fast rule can always be followed, and that is observing the moisture of the soil. If samples of earth, taken at depths of 6 or 8 inches, are pressed in the hands and maintain their shape, there is sufficient moisture, while if they crumble the crop is sorely in need of water. The latter condition should never be permitted to exist. Experience and close observation will decide on the best time to irrigate. Too much water is as harmful as too little, and without cultivation both are conducive to small returns.

WATER SUPPLY AND ITS USE.

The greater part of the area devoted to beet culture in irrigated sections is under gravity systems, the balance being under pumping plants. Notable among the latter is the Garden City district of Kansas and the bulk of the fields in California. The beets require irrigation during the months in which streams are at their lowest stage, and it is therefore important that an adequate supply be obtainable. The reservoir systems of northeastern Colorado show the excellent provisions which may be made for storing water for use when water is low in the streams. These reservoirs, which are of various capacities, are none of them of any great extent, and advantage has been taken of the various depressions throughout that section to make them, so that none represents any great cost. During the period of high water in the natural water courses, when there is very little demand for irrigation, the reservoirs are filled with water, which is held in reserve for later use. In extent this is the greatest beet-producing region in the United States.

Between the South Platte River and the mountains from Boulder to Sterling in Colorado, a distance of about 120 miles, there are nine factories, with a capacity of about 8,000 tons per day, and an area of 70,000 to 80,000 acres devoted to sugar beets each year. This is made possible by the excellent arrangement of the water supply. Good land with water rights will range in price from \$150 to \$250 per acre. Water rights on ditches are valued at \$30 to \$60 per acre, and where reservoirs are owned separately from ditches the rights entitle the owner to a certain number of cubic feet of water, in accordance with the number of shares owned and the quantity of water in the reservoir during the season. Water rights in the canals are usually based on a continuous flow of 1 cubic foot per second for each 50 to 100 acres for a period of 200 days (April 15 to November 1), which, if used continuously, would amount to a depth of 4 to 8 feet on each acre, but this quantity is never secured. The ditch supply is usually augmented by water from the reservoirs and an average use of water on the beet fields of this district is 24 to 36 inches in depth. The quantity applied at each irrigation depends largely upon the dryness of the soil and the manner of distribution and was found to be from 6 inches to 1 foot in depth. Where the larger amounts were used there was always considerable waste from the fields, and this may be said to be a condition common to nearly all irrigated areas. With careful handling and proper preparation of the surface a quantity equivalent to 6 inches or less of rainfall should be sufficient, even on dry soil, to thoroughly saturate the soil without waste. In seasons of drought, when the water supply is below normal, priority of rights of the canal companies plays an important part in the amount received, as those

who have first rights are entitled to the full amount of their appropriation before later appropriators receive their share; but the renting of shares in canals and reservoirs by owners who have little or no use for the water is common and arrangements are generally made whereby all who need water for irrigation are supplied, although very often in limited quantities. Where water is rented from a reservoir the charge ranges from \$50 to \$80 for 1,000,000 cubic feet, or sufficient to cover about 23 acres to a depth of 1 foot. Besides the purchase of water rights, a yearly charge is made for the maintenance of canals which averages from 40 to 75 cents per acre, depending upon the work necessary to keep the system in good repair.

The southeastern Colorado field is also an extensive one and contains six factories in a distance of approximately 150 miles, or from Pueblo to Holly. With the exception of the Sugar City plant, about 12 miles north of Rocky Ford, all are in the valley of the Arkansas River and, including the above exception, receive their water supply from that source and its tributaries. Water rights and the quantities used are about the same as in the South Platte Valley, but winter irrigation is practiced to some extent on account of a more limited precipitation at that time. Here, again, the storage of flood waters in connection with the canal systems shows the far-sighted policy of irrigation companies, particularly in the case of the Twin Lakes Canal, which supplies the Sugar City district with water. Although the owners of this canal have a late priority in the river, which would greatly limit their flow in dry seasons, the two large reservoirs owned by them near Leadville, Colo., can be drawn on in the latter part of the season when the river is low and they therefore have an ample supply. Winter irrigation in this district is more common than in other sections of the State, and the country surrounding Ordway and Sugar City is one of the best and most productive beet-growing sections.

On the government project near Garden City, Kans., the charge for water rights is \$35 per acre, with an annual maintenance charge of \$2.75 per acre. The duty is 2 acre-feet per acre, or 24 inches, in depth. For a pumping proposition this is very reasonable. Appropriators diverting water from the Arkansas River at this point can not rely upon the supply, as the stream is often dry, so that such rights have little value, and pumping plants are in general use.

In the Bear River Valley of Utah the cost of a right to water is \$35 per acre, with an annual charge of \$1 for maintenance. Water is rented at \$3 per acre per year. A right entitles the farmer to the use of 1 cubic foot per second continuous flow during the irrigating period for each 80 acres, or sufficient to cover each acre to a depth of 3 feet. Beet land with water rights has the same value as in Colorado,

The beet fields of Idaho are all in the valleys of the Snake River and its tributaries, and the supply of water is generally ample throughout the season and its cost lower than in the districts already described. The Payette and Boise valleys in Idaho have an unusually favorable situation, with a mild climate due to lower elevations. A large reclamation project of the Government is now under construction there, which will dispose of water to the farmers at \$30 per acre, with an annual charge of 40 cents. This is somewhat higher than some of the private ditches, but is about the average in this section.

California conditions, as before mentioned, are distinct from those of any other field. The three factories in the great interior valley at Hamilton, Visalia, and Corcoran have been in operation such a short time that they need not be considered. The fields tributary to Alvarado, the oldest factory, need practically no irrigation, although the company controlling this factory is arranging to irrigate about 5,000 acres in the lower part of the Livermore Valley. The fields tributary to the other five factories, especially the one at Spreckles in the Salinas Valley, are irrigated to some extent, the water being secured almost entirely by pumping. The cost varies greatly with the size of the plant, the area under it, and the height to which the water must be raised, so that without going much into detail no accurate information can be given. The Spreckles Sugar Company makes a charge of \$3.75 for each acre winter irrigated, which would mean one irrigation, using either the waste from the factory or pumping fresh water from wells or from the Salinas River. The amount used depends upon soil conditions, but an attempt is made to give sufficient, so that it will penetrate to a depth where it meets the moisture in the soil. As the land is checked permanently into basins, the checks are allowed to fill until all the land in each check is well covered. Irrigation while the crop is growing is rarely practiced in the neighborhood of the factory, but in the upper part of the Salinas Valley from Gonzales to King City it is a necessity in most years. During the season of 1908 the beets on this company's ranches near Soledad and King City received two irrigations with excellent results. Large areas are now being prepared for irrigation in this valley to produce beets for the Spreckles factory, which has the distinction of being the largest in the world, having a capacity of 3,000 tons of beets in twenty-four hours. These areas will all be served by pumping plants and their leveling and checking alone will mean an outlay of \$20 to \$30 per acre. In the beet fields of the southern coast region of the State winter irrigating is almost universal. At Chino, Los Alamitos, and Compton one irrigation, and on rare occasions two irrigations, are given the growing crop in dry years, slip-joint pipe, before described, being used. The cost for each irrigation varies from \$2 to \$4 per acre.

COST OF GROWING AND THE RETURNS.

The average yield per acre for this crop in the irrigated States is 10 to 12 tons, but this should not be taken as a basis for figuring returns, as it represents both good and poor farming methods. Those growers who by their industry and forethought have made a success in producing sugar beets can alone be considered, and it will be safe to say that their average yield per acre is approximately 17 tons. Yields as high as 36 tons per acre have been noted, and from 20 to 25 tons are not unusual. On a flat-rate basis \$4.25 to \$5.60 has been paid per ton, the latter figure for siloed beets, while where payments are based on the percentage of sugar and purity, as high as \$6.75 per ton has been received.

The largest single item in the cost of growing this crop is the hand labor, consisting of bunching, thinning, hoeing, and topping. The usual price where all is included in one contract is \$20 per acre. A number of growers offer a bonus to the contractor of so much per ton for every ton per acre above a certain yield, and thereby give an incentive to good and careful work. Where each operation is contracted for separately, the following prices are generally the rule:

Bunching and thinning-----	\$6.00
Second hoeing -----	2.50
Third hoeing -----	1.50

Topping, when separate from the other operations, is arranged for at so much per ton, depending on the yield per acre, for the reason that a good crop will save the workers a good deal of time in moving around to their work. Fifty cents per ton for a 10-ton crop and up to 15; 40 cents above 15 and up to 20; and 30 cents above 20 tons per acre, are approximately the ruling rates.

Hauling to the factories or the railroads is generally arranged so that the distance does not exceed 5 or 6 miles. An average would be 3 miles, for which 50 cents per ton is generally charged.

From figures gathered throughout the district under discussion the following items of average cost are given, which do not include original leveling of the land, interest, and depreciation on farm implements, or fertilizing, nor is the interest on the original investment considered:

Cost and profit from growing sugar beets.

	Per acre.
17 tons of beets, at \$5, flat rate-----	\$85.00
Plowing land 10 to 12 inches deep-----	\$3.00
Harrowing, leveling, cultivating, and preparing seed bed-----	2.00
Drilling in seed-----	.50
20 pounds seed-----	2.00
Cultivating five times, at 40 cents-----	2.00
Furrowing twice-----	1.00
Irrigating three times—labor-----	3.00
Thinning, hoeing, and topping—contract-----	20.00
Plowing out-----	2.00
Hauling, at 50 cents per ton (17-ton crop)-----	8.50
Water charge for maintenance of canals-----	.75
 Total cost of raising-----	 44.75
Profit per acre-----	40.25

In California the hand-labor item is usually less, but the cost of water for irrigation is higher, so that the total is about the same. Generally speaking, an 8-ton or 10-ton crop will just about pay the expense of growing, while anything above that yield will be profitable, and as the tonnage increases the greater the returns in proportion. On smaller fields the grower and his family often do all or the greater part of the work themselves, so that they earn good wages besides the profit from a good yield. Where beet land is rented for cash \$8 to \$15 per acre is charged, which includes water rights, while for share rent one-fourth of the crop is the usual rate.

RESULTS OF EXPERIMENTS IN SUGAR-BEET IRRIGATION.

Early in 1905 several of the sugar companies in Colorado presented a request to this Department asking for an investigation into the growing of sugar beets under irrigation, which would tend to determine methods, time of application, and quantities of water necessary to obtain best results. Two points were selected for the experiment stations, land, water, and labor being furnished by the sugar companies cooperating. Loveland, representing conditions in northwestern Colorado, and Rocky Ford as typical of southeastern Colorado, were chosen. For the years 1905 and 1906 the Great Western Sugar Company was the cooperating party at Loveland, while the American Beet Sugar Company at Rocky Ford has assisted continuously during the past four years. The soil at the two places is similar, being a clay loam of good depth. The climate also is very much alike except for a smaller annual precipitation at Rocky Ford. Methods of irrigation differ in that the every-row system is practiced at Loveland and the alternate row at Rocky Ford. The

number of cultivations given the beets and their care were better at the former place. In a general way the objects of the experiments were to determine the effect of different numbers of irrigations and different quantities of water applied at each irrigation and in the aggregate; the difference between the effect of the use of small lath boxes and open cuts in the ditch banks on the quantities of water used and the depth of percolation; the effect of alternate and every-row irrigation, both in open and boxed furrows; the effect of the number of cultivations both before and after irrigation and their general effect on yield, sugar content, and purity of the beets.

The various experiment plats were situated in larger beet fields and were under exactly similar conditions as to preparation of the soil, time of planting, etc. Each had an area of 0.5 to 1 acre, and they were separated by strips of bare land 6 feet wide, so that water ap-

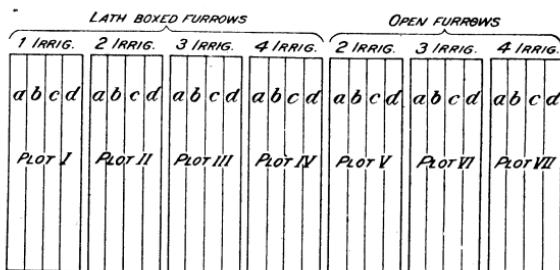


FIG. 14.—Plan of experimental field: *a*, Every row, no cultivation; *b*, every row, thorough cultivation; *c*, alternate row, thorough cultivation; *d*, alternate row, no cultivation.

plied to one would not affect its neighbors. Seven plats (fig. 14) were used, each of which received irrigations as follows:

Number of irrigations given to plats.

Number of plats.	Number of irrigations.	Method of irrigation.	Number of plats.	Number of irrigations.	Method of irrigation.
1	1	Lathbox, one-half every row; one-half alternate rows.	5	2	Open cut, one-half every row; one-half alternate rows.
2	2	Do.	6	3	Do.
3	3	Do.	7	4	Do.
4	4	Do.			

A record of all operations on a section of the adjacent beet field was also taken, the field being handled by the owner in accordance with his usual practice. Cipoletti weirs and recording registers were installed, so that the amount of water applied could be carefully measured. Beets were planted in rows 20 inches apart and thinned to as near 10 inches as possible.

At Rocky Ford, during the seasons of 1905 and 1906, the selection of experiment ground was unfortunate, and although the investiga-

tions bore out the conclusions as to results, the yield was low. In considering results obtained it must be kept in mind that the meteorological conditions vary from year to year, and that this has a large bearing on the yields. At Loveland the rainfall throughout the summer of 1906 was plentiful and well distributed, and two applications of water gave larger returns than either three or four applications, although as a rule the yield would increase with the number of irrigations up to a certain point, after which there would be a decrease. The experiments this year showed conclusively what would be expected—that with too much water the tops will make a rank, heavy growth without a corresponding development of the root. As the results this year are somewhat unusual as compared to those of the other years, they are given separately, as follows:

Effect of number of irrigations upon yield and quality of beets, disregarding methods.

Number of irrigations and plats.	Depth applied.	Average depth each irrigation.	Yield per acre.	Sugar.	Purity.
1	0.46	0.46	17.41	14.1	81.8
2	.94	.47	20.38	14.1	82.1
3	1.35	.45	17.45	14.0	83.2
4	1.69	.42	17.20	13.2	81.3

The seed was planted on April 6, and the rainfall during the growing period was as follows:

Rainfall, summer of 1906, Loveland, Colo.

Month.	Inches.	Month.	Inches.
April.....	4.06	August.....	1.07
May.....	2.21	September.....	2.95
June.....	1.80		
July.....	2.41	Total	14.50

This rainfall and the irrigation water constitute the moisture received during the growing season. Plats 3 and 4 showed throughout a very rank growth of leaves, and from their appearance one unfamiliar with the conditions would not have hesitated an instant in pointing them out as producing a heavier tonnage than either plat 1 or plat 2. When the beets were pulled, however, they were short and did not show a diameter through the thickest portion which was in any way proportionate with the top. Two irrigations were sufficient to produce the heaviest yield, while one gave better results than four. It is interesting also to note the effect of the use

of lath boxes and open furrows with two irrigations in this experiment, as follows:

Yield of beets under alternate and every-row irrigation.

Method of irrigation.	Yield per acre.	Depth applied in two irrigations.	Average depth for each irrigation.
	Tons.	Feet.	Foot.
Lath boxes every furrow.....	24.58	0.86	0.43
Lath boxes alternate furrows.....	20.46	1.05	.53
Open cut every furrow.....	16.11	.92	.46

This shows a marked advantage in favor of the every-furrow irrigation controlled by lath boxes.

The year 1908, being abnormal, will not be included in the summary of results, but before discussing this summary it may be stated that an investigation of this sort covers a wide range, which has been carried on to only a limited extent so far. It is, however, proposed to continue the work and determine the effects of many other practices, such as depths of furrows and cultivations, times of applying water, day and night irrigation, etc. It is hardly fair to base conclusions on the results from one year, as the foregoing has shown. The following summary gives three years' record of practically the same experiment:

Effect of number of irrigations upon yield and quality of beets, disregarding methods.

Number of irrigations.	Depth of water applied.	Average depth each irrigation.	Yield per acre.	Sugar.	Purity.
	Feet.	Foot.	Tons.	Per cent.	Per cent.
1	0.51	0.51	9.67	14.7	82.7
2	.88	.41	10.79	15.7	83.8
3	1.40	.47	11.78	14.9	82.5
4	1.62	.41	12.82	14.6	82.7

It will be noted that the sugar percentage under one irrigation is low, and this is accounted for by the fact that the beets had matured in the summer some time before they were harvested, due to lack of water to keep them growing. Samples taken at Loveland during 1905 show this to be the case. The field superintendent of the sugar company commenced taking these samples September 12 from all the plats, and continued to do so each week until they were harvested on October 12. It will be noted in the following table that plats 2, 3, and 4 (corresponding to the number of irrigations each received) increased in sugar and purity, as plat 1 decreased.

Sugar content and purity of beets at different dates.

Number of plat.	Date of sampling.	Sugar.	Purity.	Number of plat.	Date of sampling.	Sugar.	Purity.
		Per cent.	Per cent.			Per cent.	Per cent.
1	September 19	17.4	85.0	3	September 19	13.4	77.5
1	September 26	16.1	83.2	3	September 26	13.8	83.1
1	October 1	15.2	84.4	3	October 1	14.7	83.6
1	October 12	14.3	84.2	3	October 12	14.6	84.4
2	September 19	14.0	82.2	4	September 19	13.6	82.9
2	September 26	15.4	84.3	4	September 26	14.2	85.5
2	October 1	15.5	85.6	4	October 1	14.1	84.0
2	October 12	16.7	87.8	4	October 12	13.9	83.3

Two irrigations gave the highest sugar percentage and purity throughout, which is proof that these beets ripened better than the other plats, although the tonnage per acre for that year favors more applications of water.

The results of the use of lath boxes to control the distribution of water to the furrows, as compared with the open cuts in the ditch banks, are summarized as follows:

Effect of use of lath boxes to control flow to furrows.

Number of irrigations.	Method.	Depth applied.	Average depth per irrigation.	Yield per acre.	
			Feet.	Foot.	Tons.
1	Box	0.48			10.77
1	Open ^a .....		.67	.34	14.10
2	Box .....		.68	.34	11.96
2	Open		1.53	.51	17.10
3	Box		1.15	.38	14.20
3	Open		1.67	.42	18.22
4	Box		1.70	.43	15.00
4	Open				

^a No open furrows irrigated once.

The great discrepancy in tonnage between plats supplied by lath boxes and by open furrows can be attributed largely to deeper penetration of the water under the box method, due to its slow flow. Although the furrows were of equal length—an average of 350 feet—it required five to six hours for the water to reach the end of a furrow supplied by boxes, while one to two hours were sufficient where open cuts were used, and considerable waste water ran off the fields before the water could be shut off. If the water had been allowed to flow for an hour or so after reaching the end of the furrows there would not have been such marked difference in tonnage, but the amount of water used would have been greatly increased. This was found to be the case where results from the experiment plats were compared with those from the nearby beet field, on which nearly twice as much water was used for each irrigation as was used on the experiments. To say

that the extra water was wasted entirely would be erroneous, for provisions were usually made to collect the waste in a ditch at the lower end of the field and apply it elsewhere, but there is conclusive evidence that the small-box distribution is far more economical than the open-cut distribution.

The results with the alternate and every row irrigation with boxed furrows were as follows:

Effect of alternate and every row irrigation on yield of beets.

Number of irrigations.	Method.	Depth applied.	Average depth per irrigation.	Yield per acre.
1	Alternate row.....	Feet. 0.40	Foot. 0.40	Tons. 10.04
1	Every row .....	.57	.57	10.06
2	Alternate row.....	.96	.48	12.79
2	Every row	1.04	.57	13.98
3	Alternate row.....	1.16	.39	13.07
3	Every row	1.54	.51	14.07
4	Alternate row.....	1.41	.35	12.86
4	Every row	1.64	.41	13.92

It will be observed that in each case the every row irrigation shows an increase over the alternate row irrigation, and here, too, it is more than likely that if water had been permitted to run until it had met between the alternate rows the difference in yields would have been less, but this would have entailed the use of considerably more water and a consequent waste at the lower end of the field. It merely proves that for economical use of water better results can be obtained in every row irrigation than in the alternate row method. No accurate data can be given of alternate and every row irrigation with open cut-out, as it was impossible to so confine the water with this method that it would keep within the limits of the furrows.

A comparison of the neighboring fields which were handled in accordance with customary usage and the experiment plats fully proves the above conclusions, but it is possible to use only the results at Loveland during 1905 and 1906, as in the other years the comparisons are of little value, due to conditions which could not be foreseen. However, the fields reported in the table which is given below were adjoining the experiment plats and the general conditions were about the same. As stated before, the practice here is to use the every row method, with open cut-outs in the head ditch.

Comparison of experiment plats with adjoining general field, 1905-6.

Plat.	Method.	Number of irrigations.	Depth applied.	Average depth.	Yield per acre.
1905: Experiment plat No. 3...	Every row; boxed furrows.....	3	Feet. 1.37 2.90	Feet. 0.46 .97	Tons. 16.78 14.00
	General field.....				
1906: Experiment plat No. 3... Experiment plat No. 5... General field.....	Every row; boxed furrows.....	2	1.05 .92	.53 .46	24.58 16.11
	Every row; open cut.....				
	.....do.....	2	2.82	1.41	21.13

There was no open-cut furrow experiment plat during 1905, so that the comparison there is lost, but the large amounts of water used on the general field during both years were due to the large heads and allowing the same head to continue for an hour or so after the water had reached the end of the furrow. Arrangements were such that no weir could be placed to measure the run-off in either year, so that this data is lost, but on the experiment plats sufficient water to reach only to the ends of the furrows was applied and there was little or no waste.

CONCLUSIONS.

The results of these experiments, as well as those obtained in practice at Rocky Ford, Colo., and in the Payette and Boise valleys, in Idaho, all point to the advantage of the control of the flow to furrows by lath boxes or pipes. The slowness with which the water moves permits of its deep penetration into the soil, prevents waste at the lower end of the field, and the use of the boxes saves considerable labor after they are once installed. Yields are better also, due to confining the water to the furrows and not permitting it to wet the top soil next to the beets. The thorough saturation which it gives is far better and less costly than a number of lighter irrigations, which are given in some of the localities. The number of irrigations needed depends largely on the season and whether the beets are paid for on a flat-rate basis or according to the sugar content. If on the flat rate, more water is required, but it must be remembered that keeping the soil continually wet will reduce the tonnage instead of increasing it, as the results at Loveland during 1906 clearly show, while there is the danger of ruining the land by raising the water table and producing a swamp. The beets under such conditions will be slow to ripen, and there is the liability of their refusal by the factory, due to too large size and low sugar percentage.

If a contract calls for percentage payments it will require a more thorough and careful understanding and study of conditions, so that both good tonnage and high sugar content may be secured. As has

been shown, the beets must ripen at the time of harvest so as to contain their greatest values in sugar, and the application of water must be such as to cause a continuous healthy growth throughout the season, so that the tonnage is not sacrificed. A contract of this kind is equally beneficial to the factory and the grower who exercises care and judgment in the handling of the crop, which results in better returns on the average than the flat-rate contract. For example, a 17-ton crop at \$4.50 per ton on a flat rate would bring \$76.50, while if the same crop contained 17 per cent of sugar it would bring, on the percentage rate, \$4.50 for 15 per cent, and an increase of 25 cents for each 1 per cent over—\$5 a ton, or \$85, which is equal to 11 per cent more than the flat rate.

The enormous consumption of sugar in the United States, amounting to more than one-fifth of the entire sugar production of the world, and the small quantity which is of home growth and manufacture, point to a field of large possibilities and the rapid colonization of the irrigated West.

